SNOW COVERED PEDESTRIAN CROSSWALK ENHANCEMENT VIA PROJECTED LIGHT DEMARCATION

By

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By

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Abstract

Snow coverage of streets in Anchorage, Alaska, can visually block pedestrians and drivers from viewing painted crosswalk demarcations. This study investigates the potential of utilizing light projected onto the snow's surface to mimic the intended demarcation of the painted demarcation during snow coverage.

This is investigated via hypothetically fitting an existing crosswalk location with available-for-purchase manufactured light projectors. The configuration is then evaluated for angle of light projection, discomfort glare, and contrast.

The proposed installation is found to be theoretically acceptable. However, further analysis could be performed regarding effective visual detection of contrast during driving conditions and regarding acceptable levels of disability glare.

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Introduction

Background

Anchorage, Alaska, USA, is a city located primarily within the 61st degree North latitude (Google Incorporated, 2015) with a population of 291,826 (State of Alaska, 2010). Anchorage experiences an average of 189 cm of snowfall per year which occurs primarily within the months of October through April (National Oceanic and Atmospheric Administration, 2015).

A common result of the annual snowfall in Anchorage Alaska is the coverage of painted-on-pavement pedestrian crosswalk demarcations by snowfall. The snow coverage over these painted markings on crosswalks can decrease or eliminate the ability of pedestrians and vehicle operators to see the painted markers.

Problem Statement

Snow coverage of painted crosswalk lines in Anchorage, Alaska, often eliminates the functional purpose of the painted crosswalk lines via visually obstructing the lines from both drivers and pedestrians view. The covering of the visual marker results in a reduced ability of pedestrians to stay within the predetermined crosswalk boundary and a reduced ability of drivers to determine the finite bounds of the crosswalk. Pedestrian excursions out of the crosswalk bounds and driver incursions into the crosswalk area likely increase the probability of vehicle pedestrian accidents.

Hypothesis

Projected light can be utilized to visually simulate a crosswalk demarcation on snow covered streets in some applications without creating unacceptable visual side effects to drivers and pedestrians.

Scope of work

This study includes a review of applicable definitions and terms needed to evaluate the proposed hypothesis. The review of terms and definitions is followed by a dimensional description of the existing crosswalk selected for analysis. These existing dimensions are utilized to gain dimensional approximations of a proposed projected light installation. Utilizing the installed dimensions, a system lighting characteristics analysis of the proposed installation is performed to evaluate applicability of the proposed lighting system.

Terms and definitions

This study utilizes the International System (SI) of units of measure. The referenced units, measurements/terms, and their associated symbols are outlined in Table 1.

Table 1. Measurements / Terms, Units and Symbols (FHWA, 2008, ANSI/IES, 2014, and NASA, 2015).

Measurement / Term	Unit(s)	Symbol
Length	Meter	m
Area	Square meter	m^2
Visible Light Intensity	Lumen (candela x steradian)	I
Illuminance	Lumen / Meter^2 (lux)	E
Luminance	Candela / Meter^2	L
Contrast	unitless	C
Albedo	unitless	α

Definitions

The US Department of Transportation, Federal Highway Administration (FHWA), the American National Standards Institute (ANSI), the Illuminating Engineering Society (IES), and the North American Space Agency (NASA) offer definitions of terms that are referenced in this paper. Those definitions include:

Illuminance (E): A measure of the amount of light that falls on a surface per unit area. (FHWA, 2008).

Luminance (L): The light emitted from a surface in a specific direction per unit area of the surface (FHWA, 2008).

Weber Contrast (C): The difference of two luminances divided by the lower luminance (FHWA, 2008).

Discomfort Glare: Glare producing discomfort. It does not necessarily interfere with visual performance or visibility (ANSI/IES, 2014).

Disability Glare: Glare resulting in reduced visual performance and visibility. It is often accompanied by discomfort (ANSI/IES, 2014).

Albedo (α): A ratio of the radiation reflected by a surface to that incident on it, where a 100% reflecting white body has a value of one, and a 0% reflecting black body has an albedo of zero (NASA, 2015).

Existing Dimensions

Selected Crosswalk

For the purpose of this study and analysis, an existing Anchorage crosswalk was chosen as a proposed site for usage of projected light crosswalk demarcation. This crosswalk spans Mountain View Drive at the intersection of Mountain View Drive and North Flower Street. This crosswalk was chosen for specific analysis due to its design simplicity relative to other Anchorage crosswalks, and the geometry of its various components.

Figure 1 is a summer season view of the Mountain View Drive crosswalk looking toward the East.

Figure 1: Mountain View Drive and North Flower Street Crosswalk. View looking East (Google Inc., 2015).

The approximate dimensions of the Mountain View crosswalk and intersection are outlined in the Figures 2 and 3. Dimensions outlined in the figures were acquired from both direct measurement and relative measurement.

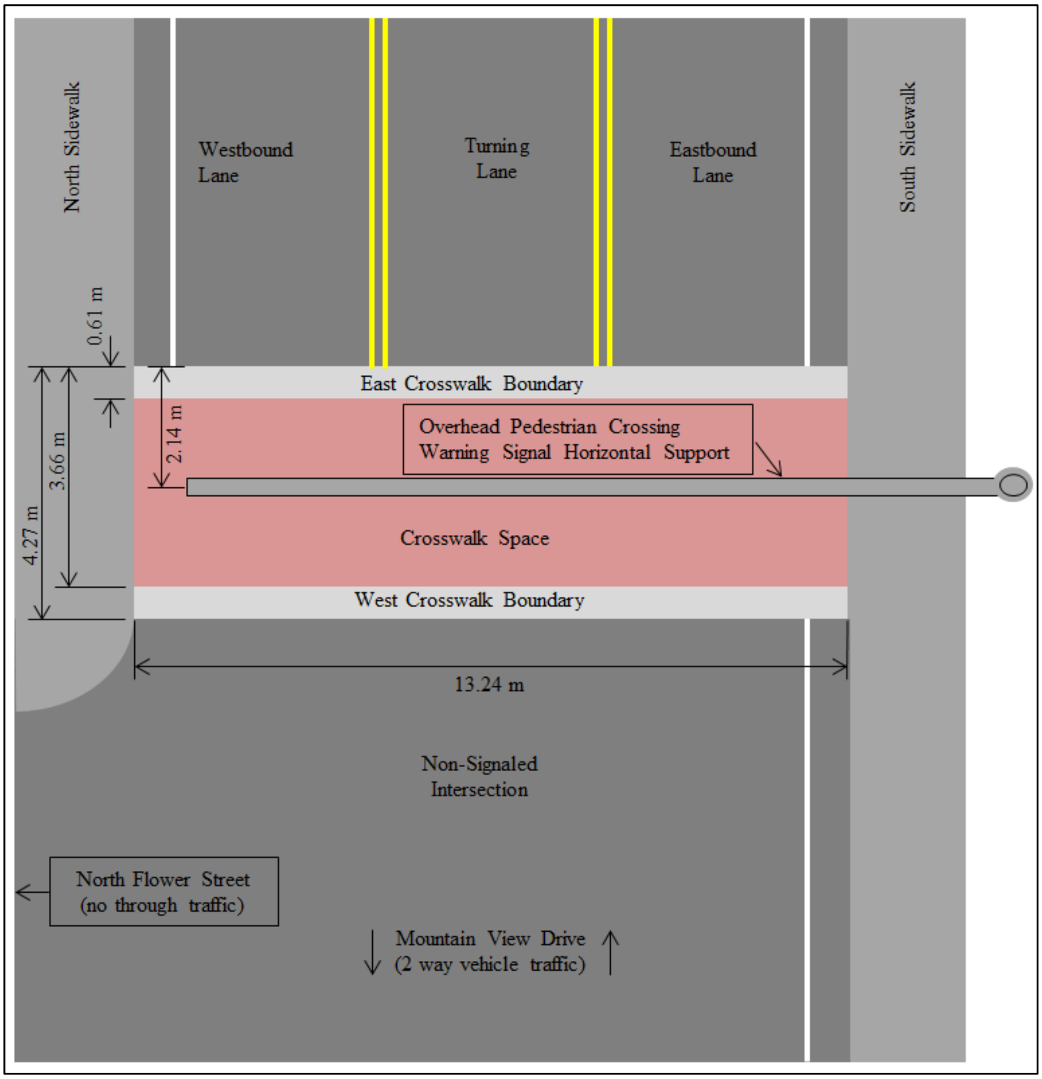

Figure 2: Plan view of Mountain View Drive and North Flower Street intersection and approximate dimensions.

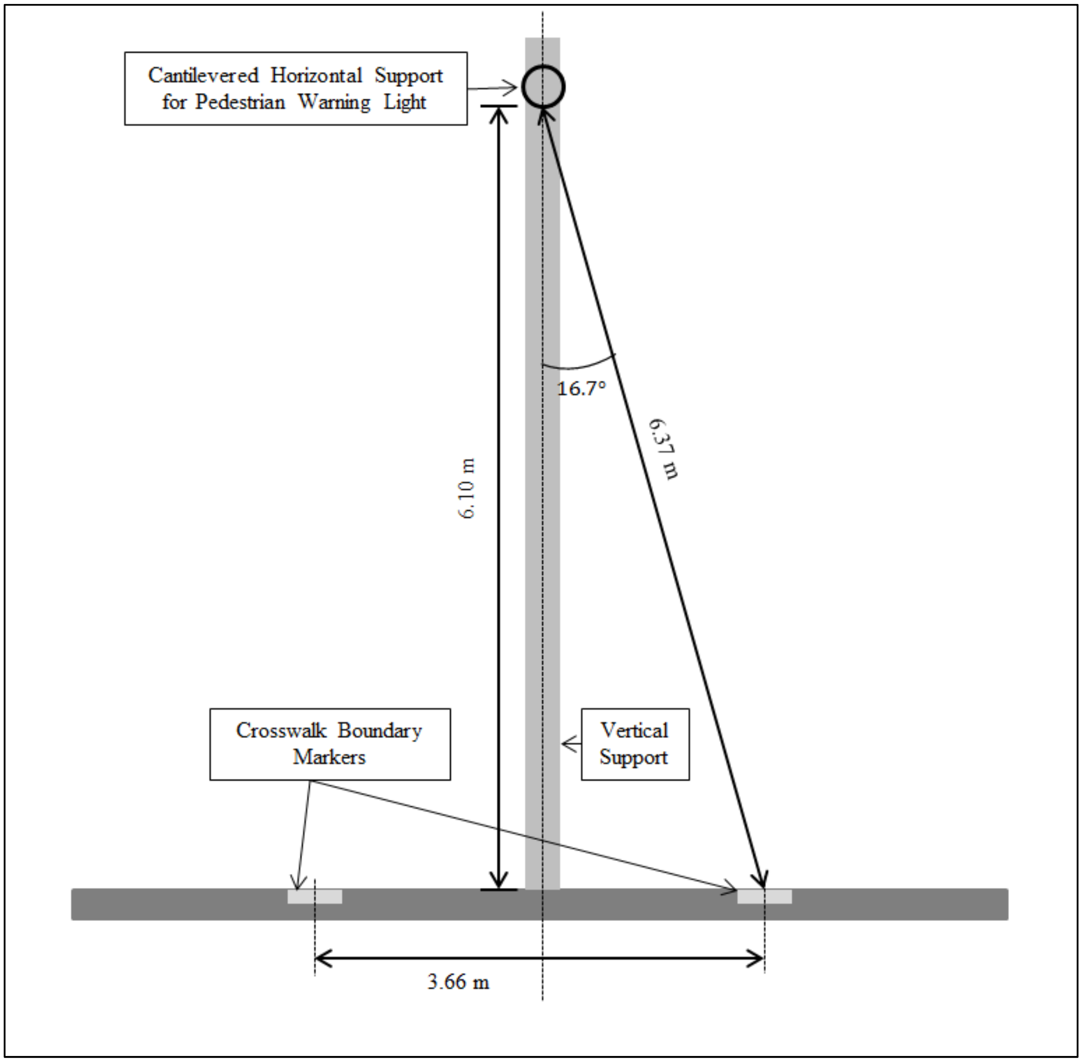

Figure 3: Cross Section view of the Mountain View Drive Crosswalk with approximate dimensions.

Proposed Projector Installation

Projected Light Installation

Utilizing the existing geometry of the Mountain View Drive crosswalk outlined in the figures above, the geometry and the general dimensions of the proposed projected light infrastructure can be inferred for the purpose of this analysis.

The primary infrastructure required for the proposed projected light demarcation at this location is the overhead light projectors. Many vendors offer various products that could be used as the proposed light projectors for this crosswalk application. A common lighting industry term found to describe the type of projector needed for this application is a ‘projected light pattern projector’ that this paper will refer to as simply ‘projector’.

In order to apply a comprehensive set of projector specifications to this study, a Martin brand ‘Exterior 400 Image Projector’ model projector will be utilized for analysis (Martin Inc., 2015). The Exterior 400 Image Projector may not be the ideal projector for this application for various reasons beyond its light projection characteristics, but it is chosen for this study due to the extensive product information made available for this study by Martin Inc.

The applicable Martin Exterior 400 Image Projector outfitted with a wide lens has performance specifications that are supplied in the table below. All table values are given assuming a vertical mounting position of 6.1 m above the pavement surface.

Table 2: Martin Exterior 400 image projector performance at proposed 6.37 m from projected surface with wide lens (Martin Inc., 2015).

Illuminance (maximum)	913.7 lux
Total Output (per projector)	7500 lumens
Illuminated diameter (maximum)	4.6 meters

The illuminated diameter distance of 4.6 m from the table above provides the guidance needed to properly fit the Martin projectors to the geometry of the proposed Mountain View crosswalk. Figures 4 and 5 illustrate the projector mounting positions to the overhead horizontal support given the illuminated diameter maximum distance of 4.6 m at a range of 6.37 m from the pavement.

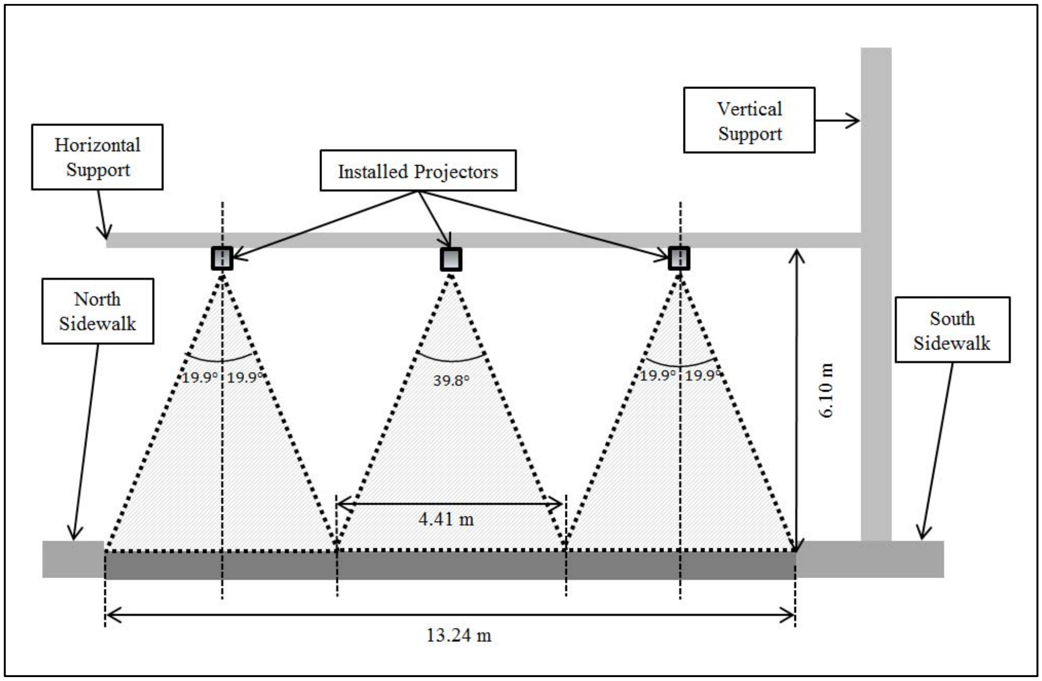

Figure 4: Street cross section view of installed projectors and light patterns.

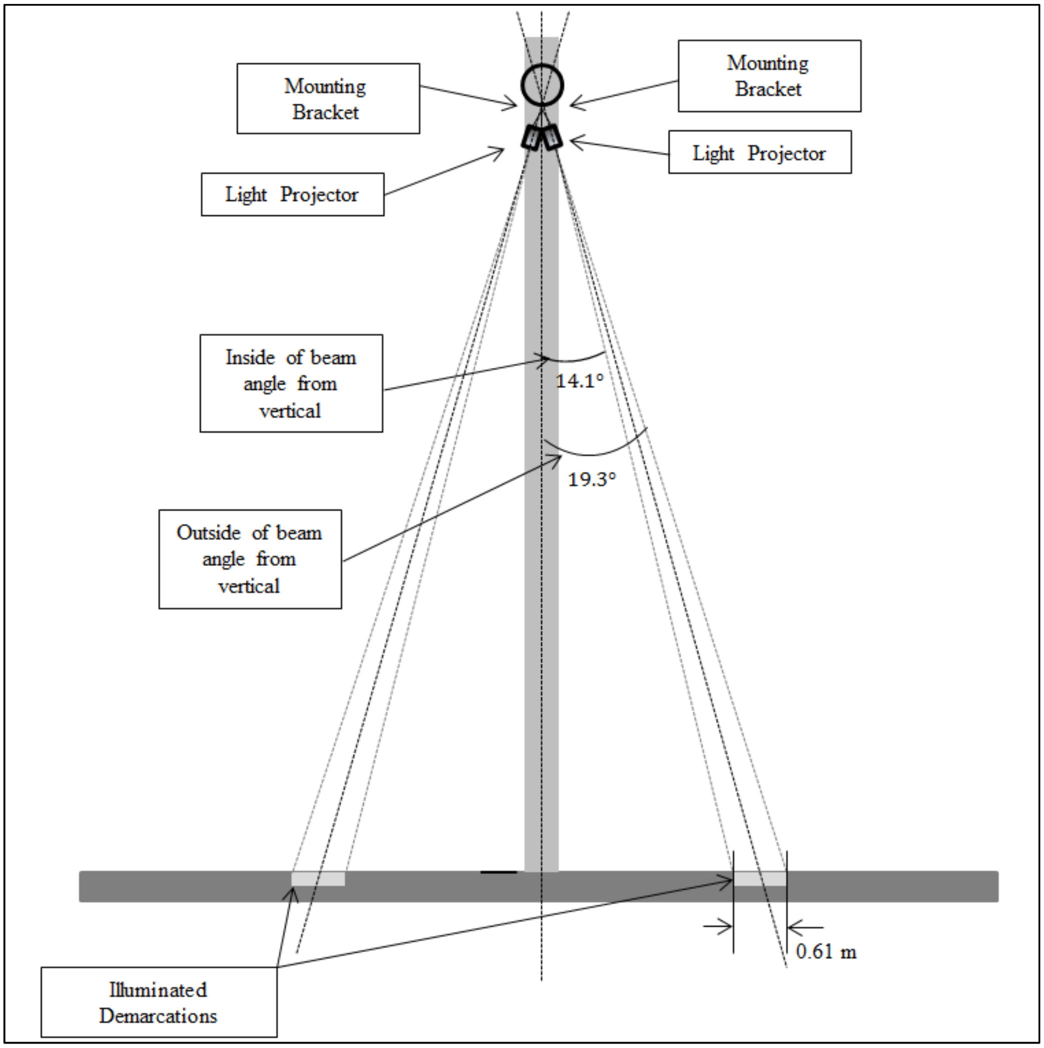

Figure 5: Crosswalk cross section view of installed projectors and light patterns.

This study does not investigate the details of the structural and electrical analysis needed to properly install projectors at the proposed location. The assumption is made that the structural and electrical connections needed for proper mounting and powering/controlling is relatively routine.

Light analysis

Light Characteristics

In order to be an effective means of demarcation when the painted crosswalk markings are covered by snow, the projected light demarcation needs to provide appropriate contrast to serve as a visual demarcation, and appropriately operate without providing inappropriate visual impairment to drivers and pedestrians.

Angle of Projection

The angle of projection of light is important due to the potential for the projected light to interfere with pedestrian and driver vision. Via ANSI/IES RP-8-14, the Illuminating Engineering Society indicates that pedestrians are shielded by their eyebrows from luminaires above 45 degrees from the direction of view, and that most drivers are shielded from luminaires over 20 degrees above horizontal (ANSI/IES, 2014). Figure 5 indicates that the projected light configuration at the Mountain View Drive location would produce a maximum angle of 19.3 degrees from vertical in the East/West directions and a maximum angle of 19.9 degrees from vertical in the North/South directions. These angles of projection would be appropriate with respect to the ANSI/IES RP-8-14 guidance regarding Field of View.

Reflectivity and Discomfort Glare

For the purpose of this paper, the reflection of a surface to an imposed illumination will be approximated by published albedo values.

The snow surface that can cover the painted crosswalk lines can range in its albedo. Natural snow has an albedo range of approximately 0.55 to 0.8 (NASA, 2015). Snow on street surfaces can be disturbed by cars and pedestrians resulting in compaction and mixing with dark fine grain minerals. This disturbance and addition of dark particles would potentially lower the albedo of the snow covering the painted markings to an earth tone color similar to the albedo of sand. The albedo of sand ranges from 0.15 to 0.45 (Grover, 2012). For the purpose of this paper the maximum and minimum albedo values of 0.8 to 0.15 are used to represent the snow covering the road surface.

Albedo is taken into consideration due to the discomfort glare that may result from reflection of the proposed projected light into individuals field of vision.

Per ANSI/IES RP-8-14, discomfort glare is measured qualitatively and can be highly dependent on a person's age. A 20 year old person has an approximate discomfort glare threshold of 4200 lumens and an 80 year old person has an approximate discomfort glare threshold of 1000 lumens (ANSI/IES, 2014).

Using the more conservative discomfort glare threshold of 1000 lumens for elderly people and assuming 1 m^2 projected area, the maximum fresh snow albedo value of 0.8 multiplied by the imposed 913.7 lux illumination of the snow surface from the projectors would create a fresh snow lumination of 731.0 lumens. In dirty snow conditions the snow lumination intensity due to the projectors would be 137.1 lumens using the same methods as above. These calculated luminance values occur below the referenced disturbance glare thresholds, but it is unlikely that these values would occur in a completely dark environment given the urban setting of the crosswalk. Street lights and other light sources would contribute to the lighting of the area. The additive value of the projector light source plus other adjacent light sources would increase the total brightness of the projector lit area. Per ANSI/IES RP-8-14, recommended street lighting illumination values for high pedestrian conflict areas is 20 lux. Considering the additional light provided by street lighting and using the same assumptions as above, the maximum lumination intensity would be 747.0 lumens and a minimum lumination intensity would be 140.1 lumens.

The values and assumptions above indicate that the nighttime operation of the projectors would not exceed accepted discomfort glare thresholds.

Contrast

For appropriate visual detection of the projected light as a demarcation there must exist a visible contrast between the illuminated projected light area and the area adjacent to the projected area. The detectable contrast difference for the human eye is roughly one percent and greater (Pelli, 2013). The one percent difference in contrast, or 0.01, is calculated using the Weber equation or similar methods. Per the FHWA

Informational Report on Lighting Design for Midblock Crosswalks, the Weber Contrast equation is outlined in the equation:

$$C = \frac{(L_{object} - L_{Background})}{L_{Background}}$$

Values of ambient outdoor illuminance in the daytime during overcast and clear conditions are approximately 1,000 lux and 32,000 lux, respectively (New Buildings Institute, 2015). In the nighttime a value of 20 lux can be assumed for urban pedestrian areas as was utilized above in investigating discomfort glare (ANSI/IES, 2014).

Utilizing the assumed daytime and nighttime illuminance values and the albedo values of the snow covered surfaces, the resulting luminance of the projected area of the crosswalk and the adjacent areas can be found. The luminance values are then applied to the Weber Contrast equation to provide contrast values. Tables of lumination and contrasts for fresh snow and dirty snow are found in Table 3.

Table 3: Contrast and brightness values of fresh snow (0.8 albedo) for projected and non-projected areas.

	Ambient Illumination (lux)	Illumination of Projected Area (lux)	Projected Surface Luminance of Fresh Snow (L object)	Non-projected Surface Luminance of Fresh Snow (L background)	Fresh Snow Contrast (%)
Nighttime (street light overhead)	20	934	747	16	4570%
Daytime (overcast)	1000	1914	1531	800	91%
Daytime (clear sky direct low angle sun)	32000	32914	26331	25600	3%

Table 4: Contrast and brightness values of dirty snow (0.15 albedo) for projected and non-projected areas.

	Ambient Illumination (lux)	Illumination of Projected Area (lux)	Projected Surface Luminance of Dirty Snow (L object)	Non-projected Surface Luminance of Dirty Snow (L background)	Dirty Snow Contrast (%)
Nighttime (street light overhead)	20	934	140	3	4570%
Daytime (overcast)	1000	1914	287	150	91%
Daytime (clear sky direct low angle sun)	32000	32914	4937	4800	3%

The minimum contrast value found in Tables 3 and 4 is 3%, which occurs during clear daytime conditions. This 3% is above the 1% minimum threshold for detectable difference in contrast which signals that the projected light demarcation would be visibly detectable to the human eye in all of the outlined conditions. It is worth noting that given all other conditions being equal, albedo does not affect the Weber Contrast value.

Potential Issues

Given the nature of the unproven usage of projected light for demarcations in a cold regions urban application, the following are potential issues to be considered:

- Lumination characteristics of light on falling or blowing snow
- Lumination characteristics of water on ice
- Degradation of projector illumination due to frost buildup on lenses
- Lumination characteristics during periods of ice fog

Further Analysis

This study utilizes methods and information taken from multiple sources to generally evaluate the proposal regarding applicability. Further analysis of the characteristics of the proposed projected light demarcation system could likely be performed regarding:

- Disability glare
- Contrast improvement via colored projected light
- Visual detection of contrast minimums under driving conditions

Light characteristics could be better evaluated via utilizing a projector in a test environment. First hand quantified measurement of the light characteristics and first hand qualified human tests could validate or disprove existing assumptions, and testing would create the opportunity for visual observation under various conditions.

Future Work

Utilizing projected light for demarcation in snow conditions could be evaluated via implementing a pilot project. Such a pilot project would best fit in a no/low consequence environment given the untested nature of the lighting method of demarcation and the potential for unforeseen characteristics. Performing a pilot project at the proposed Mountain View Drive location in this paper is not recommended until further research and verification is performed due to the high consequence nature of pedestrian-vehicle accidents at a crosswalk location.

Appropriate settings for a projected light demarcation pilot project in Alaska may include:

- Parking lot or pedestrian only areas
- Various locations on the University of Alaska campuses
- Prudhoe Bay lease on Alaska’s North Slope
- Downhill and cross country ski areas

Conclusion

The proposed utilization of projected lighting for crosswalk boundary demarcation in snow conditions with existing manufactured equipment at the Mountain View Drive location is theoretically acceptable when analyzed by angle of projections, discomfort glare, and Weber contrast. Further analysis could be performed regarding effective visual detection of contrast during driving conditions and acceptable levels of disability glare.

Successful utilization of the proposed projected light demarcation system could reduce pedestrian excursions out of the crosswalk area and reduce driver incursions into the crosswalk area. The projected boundary utilized during snow covered conditions would properly delineate the designated boundary and could likely reduce the frequency of vehicle pedestrian accidents associated with inadvertent boundary incursions and excursions.

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